Submarine launched Ballistic Missiles

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Introduction

A submarine-based ballistic missile is fired from a submerged platform underwater. There are a lot of challenges compared to a land based ballistic missile. The land-based missile is fired from a known, fixed location. The land based missile does not have to travel through water, before beginning its ballistic flight.

In the history of submarine-launched missiles of the United States, there have been 4 classes of sub, and 6 models of missiles. We will discuss all of these.

The U.S. and Russia are the primary deployers of these weapons. They are also used in a lesser degree by England, France, India, and China.

Author

The author spend 42 years as a NASA Contractor, at all of the centers. He was aboard a WW-2 submarine, the USS *Torsk* once, with his Mom, in Baltimore. He knows a lot about launch vehicles, most of which were derived from ballistic missiles, and he is familiar with their flight computers and guidance . Less so, with submarines. This book was a journey of discovery

History

The first use of cruise missiles and ballistic missiles in warfare was by the Germans in World War-2. They launched the cruise missile V-1 from fixed locations in mainland Europe against London among other targets. They did the same with the true ballistic missile, the V-2. They were planning to launch the V-2 from a canister towed by a submarine at New York.. The bottom of the container could be flooded to bring the missile upright. There was a similar program to launch the V-1 against New York, bringing the war to the New World. Too little, too late, thank the stars.

However, the United States and the Russians got their share of German scientists and skilled workers after the war.

There were no guidance computers at the time. The V-1 flew in a pre-planned direction, with a small propeller, measuring rotations. That was calibrated, and when the correct distance was reached, the missile dove. There were a lot of things that could go wrong, and did. Accurate surveys of the launch site was essential. Permanent launch sites were bombed b the Allies.

The German V-2 Field Operations Manual was captured by US forces along with missiles and launch and ground support equipment. The manual was translated at the Army's Aberdeen Proving Grounds (MD). It tells the ground troops how to launch the missile. The manual assumes a high school education. After the launch site is accurately surveyed, the missile was erected and fueled. Then, the troops were instructed to "…point fin number one towards London…" The distance was set into the timer that would shut down the engine, the missile was launched, and the support equipment made a hasty withdrawal to avoid Allied air power. Crude but effective, with no defense against it.

The Soviet Union, after World War-2, was the first to launch a ballistic missile from a submarine. Around 1956, they had 6 subs capable of this. They used liquid fuel, and had to launch from the surface.

In 1960, the US launched a Polaris missile from a submerged USS Washington. The Soviets achieved this capability by 1963.

Guidance computers for missiles.

In the 1960's, missile guidance computers were developed that could adjust the missile's trajectory after launch, but only during powered flight. These included the Univac *Athena* computer for the Air Force's Titan missile system, and the Burroughs *Mod 1* for the Atlas missile system. The Smithsonian has one of each computer. The author has direct hands-on experience with both machines.

These first two computers discussed were for employment in large hardened underground bunkers. They controller a land-based missile for the several minutes of powered flight. Then, it was on its own. From these massive machines, the onboard flight computer was derived. These guided the missile in flight, but flew along with it. Critical to the system, regardless of where the computer was located, was the navigation system. For both of the systems discussed below, we had a well-surveyed underground bunker as a starting point, and a list of (mostly Russian) target locations. The missile knew where it was starting from, and where it had to go.

Athena, for Titan

The Athena was the ground-based computer for the Titan-I missile. These units were not for flight; they exceeded weight budget by 9 tons. The idea of putting the computer onboard the vehicle was just a dream at this point.

The Univac Athena required 370 square feet of floor space underground in a hardened bunker. Using radar data input, it calculated course corrections during engine burn. It only had to work for two minutes. It was programmed in assembly language, and was a Harvard architecture, meaning the instructions and data were kept in different stores. In the case of the Athena, the instructions were kept on a magnetic drum, and the data were kept in core. Eventually, 23 machines would be built in St. Paul.

The Athena cost about $1,800,000. when new, and weighed over 18,000 lbs when shipped. It used a massive motor-generator set with 440-volt 3-phase AC input. The motor generator control unit weighed a ton, and the motor/generator itself weighed over 2 tons.

The machine was built by Sperry Rand Univac in 1957, with Seymour Cray as the chief designer. It had 256 words of 24-bit core memory for data and a 8192-word drum for program and constants. A most interesting feature was Battle Short: In this

mode, referred to as “melt-before-fail”, the power to the machine could NOT be shut off. Once in service, it was found to have a mean time to failure of 48 days, twenty times better than the original specifications.

The Titan launch complex was located underground, and a single Athena could be used with multiple missiles, launched one at a time. There were eighteen missile complexes in the U. S., each capable of launching multiple missiles. The liquid-fueled Titan's were considered to be only a stop-gap measure pending the deployment of the solid fuel Minuteman Missile, and none of the complexes were operational for more than four years. Most of these launch complexes survive, and some allow visits.

The Athena was an extremely reliable computer, which never caused a count-down hold or flight problem in all of those years. The software in the Athena computer operated from a rotating drum, and each instruction had to be spaced along the drum in such a way that the rotation time between instructions was equal to the execution time of the previous instruction. The Athena was used on over 400 missile flights, none in anger.

AN/GSQ-33, for Atlas

The Atlas' computer was the result of the von Neumann ICBM Committee. Atlas A, B, C, and D had no onboard computers and used ground-based guidance Atlas was the first intercontinental ballistic missile deployed by the United States, Weapon System 107A-1, in 1955.

The AN/GSQ-33, Burroughs SM-65 was the ground-based guidance computer for the early Atlas series of rockets. Eventually 17 units were delivered. The ones at the Eastern Test Range (Cape Canaveral) and Western Test Range (Vandenberg AFB) were used for range safety until 1978. The reliability specification was 0.96, but the machine achieved an operational reliability of 0.998. There were no errors during flights. One machine operated 24 hours per day continuously for 17 months without a critical failure.

The data word size was 28 bits, and the instruction word was 18 bits. It was a binary machine, with 38 instructions. Clock speed was just above 200 Khz. An ADD operation took 47 microseconds, and a multiply took 532 microseconds.

Memory held 1536 instructions, core had room for 256 items. Some constants could be set by switches. The machine required 208 volt power, 60 cycle, 3 phase, 20 kva from a motor-generator set. Although the cpu used transistor technology, the terminal equipment used tubes. The system included a paper tape reader, paper tape punch, and a plotter.

As a real-time control computer, the machine received missile position and velocity data from radar, and produced steering commands for transmission to the vehicle, during the few minutes of powered flight.

Development of the computer started in 1955. It was a break in tradition from the tube-type computers that were common – it was transistorized. There were three models, developed incrementally. At the time that Burroughs was contracted for the computer, there was no Atlas missile in existence. After the computer was delivered, it was termed the AN/GSQ-33, Digital Computing System. There was some thought of making a truck-mounted "portable" system, but this was never developed.

The machine was implemented with direct-coupled transistor logic. The main problem was the connection between cabinets. If a cable was disconnected while powered, the Philco driver transistor would burn out. This was encountered by the author at the Smithsonian after a large number of failures were noted during debugging of the unit. As with operational installations, the motor generator set was installed on another floor of the building, due to the noise.

NATDAN and the G-15

The Bendix G-15 computer, as the author remembers was a circa-1956 green refrigerator-sized box, with vacuum tubes, a drum

memory, and a paper tape reader on the front. He used one in his undergrad days. The G-15 went on to serve the Navy, on the USS *Compass Island*, which was a navigation ship. The Navy, before the Transit sat-nav system, was trying to provide navigation support to the Polaris. The G-15 was the test machine for the Navy's NGA-I system. NATDAN, the *North American Transistorized Digital Analyzer*, solid state, had a profile that could fit through a sub's hatch. It used disk memory.

The eventual Shipboard Inertial Navigation System (SINS) was installed on the Nuclear subs *Nautilus* and *Skate*. Both cruised under the North Pole, and the *Skate* surfaced there, showing the accuracy of the system. *Compass Island* was retired in 1980, and replaced by the USNS *Vanguard*. It in turn was replaced by the USNS *Waters*, originally a oceanographic survey ship, brought into the Navy in 1998 to support flight tests of missiles. It's home port was Cape Canaveral, Florida, and it is operated by the Military Sealift Command.

There were also Five FBM tenders for the Polaris boats, four of these converted to tenders for Poseidon. The two largest were modified to support Trident Subs.

Solid versus liquid fuel

A rocket engine can use solid fuel or liquid fuel. Solid fuel is a blend of a fuel and an oxidizer, in stable form. It can be stored for a fairly long period of time. Liquid fuel has a fuel and an oxydizer as well. Generally, these are not stored in the vehicle's tanks, but the vehicle has to be fueled before firing. Liquid fuel has a performance lead, but the delay for fueling can be a problem. For land-based missiles, in silos, the liquid fuel represented the same problem – a delay in launch. A solid fuel systems such as the Minuteman missile was a game changer. On the other hand, the Saturn-V Apollo moon rocket used liquid fuel. The Shuttle was a bit of a hybrid system, using liquid fueled main engines with strap-on solid boosters.

The earlier winged *Regulus* missile, is what we today would call a cruise missile (like the German V-1 in World War-II). The downside of the Regulus was that the sub had to surface, and remain on the surface as the missile was prepared and fired. The subs that were converted to launch the Regulus USS *Halibut*, USS *Tunny*, USS *Barbero*, and USS *Growler*. These were referred to as the *Grayback* class

Missiles for Subs

The development of onboard missile guidance computers was driven by the need to launch from submarines. Since the launch is not taking place from a pre-surveyed location, the calculations are more difficult. The exact position of the submarine must also be known. This led to the development by the Navy of the Transit system, an early predecessor of the GPS (Global Positioning System). The Transit system relied on a series of Navigation Satellites in known orbits. Once you launch the guidance computer, it only has to work for several minutes, during powered flight, and is not reused.

The early submarine-based missiles were liquid-fueled, with the UGM-27 Polaris providing the solid fuel breakthrough. First flown in 1960, it was a two-stage solid fueled unit. It was in use from 1961 through 1996. The Navy had an eye on the Army's Jupiter missile in the 1950's, and negotiated some design features to make it easier to deploy on ships and submarines. For example, it was made shorter, but wider. The safety of a liquid fuel and oxidizer stored on the vessels was an issue. All current sub-launched ballistic missiles are solid fueled.

German launch of V-1 and V-2 from submarines

Germany began developing sub-launched missiles in 1944.The code word was Pref *Stand XII*. This was in 1944, and the rocket team at Peenemunde under Von Braun were working on a project for the Navy, a V-2 missile in a towed container behind a

submarine. It was going to be deployed off New York. The difficulties were massive. The towed container would be flooded at one end to make that end sink. The sub would have to be on the surface to fuel and fire the missile. There was no good guidance system available. On land, the V-2 was launched from a carefully surveyed position, with the instructions.

Test launches of the Schweeres Wurfgerat 41 rocket launcher on both submerged and surfaced U-boat U-511 were conducted in the summer of 1942. These were simple, none-guided rockets 30 cm in diameter. The rocket launcher, type 41 could hold 6, and multiple launchers could be fitted. Tests were successful, down to a depth of 40 feet. The lack of a guidance system was a problem, and the research center at Peenemunde was heavily involved in the V-1 and V-2 at the time.

The V-1, a pulse-jet cruise missile had a range of around 150 miles. Putting these on board U-boats was considered, but wince the V-1 was a Luftwaffe (air force) project, a certain lack of cooperation made sure this never happened.

In 1943a Project code-named *Prufstand* XII! (Test Stand 12) was kicked off under great secrecy. This involved a large, water-tight container meant to be towed behind a submarine. A German type XXI boat was to tow three of these launch tubes with missiles. The tubes also contained auxiliary diesel fuel for the sub, needed for the extra drag.

For launch, a chamber at the bottom of the tubes would be flooded to put the missile in launch position. The sub had to know its position accurately. The launch was controlled from inside the boat. Since the V-2 used liquid oxygen, it is unclear whether this would be kept in the missile (which then would have needed topping up, or weather it would be stored in dewars) Time on the surface is critical to avoid being spotting by aircraft, so the launch prep had to be streamlined.

Three containers were ordered built in December 1944, and at least one was built.

The U.S. was aware of this project, and responded with operation Teardrop, which put four escort carrier groups in the North Atlantic. In March of 1945, they did intercept a wolfpack of six German type IXC u-boats. The Navy destroyed four of the six.

A contract was let to build a test version of the sub launched missile. Nothing came of the project by the end of the war. It would have been a great psychological weapon against the U. S.

Loon

The Republic-Ford JB-2, aka KGW-1 *Loon* was developed after U. S. engineers got a good look at a German V-1. The *Loon* was developed in 1944, and was slated to be used in the Invasion of Japan, but was never used in combat.

It was carried on the Aft deck of a submarine, in a water-tight container. The first installation was on the USS *Cusk*, which launched one of the missiles successfully in 1947. Another sub, the USS *Carbonero*, was also equipped with Loon tubes.

It was designated by the Navy as JB-2 or KUW-1. I had 2,200 pounds of high explosive that could be carried 150 miles. It retained the rear-mounted pulse jet engine of the German design. It was a slightly updated version of the one in the V-1.

Regulus

Regulus, SSM-N-8A was a ship- or submarine launched cruise missile, also based somewhat on the German V-1. The *Regulus* was a second generation device, using a J33 turbojet engine. JATO units were used to assist the launch.

The concept was developed during World War-II by Chance Vought Aircraft, with an initial goal of a range of 300 miles with a 4,000 pound explosive. Later, the desired payload was reduced to 3,000 pounds. Launch testing from submarines was conducted from 1947 to 1953 from the Point Mugu Naval Station in California. The subs involved were the USS *Cusk* and the USS

Carbonero. They had guidance equipment for the missile onboard.

The missile was 30 feet long with a 10 foot wingspan. It was 4 feet in diameter, an weighed 5-6 tons. It resembled a fighter jet, but with no cockpit. It could be controlled by the launching sub, a sub or ship closer to the target, or from aircraft. First launch was in 1953 from the submarine USS *Tunny.*

The Regulus was capable of carrying a nuclear war head. Eventually, the submarine USS *Barbero* was fitted with two of the *Regulus*. The subs *Grayback* and *Growler* were built specifically to deploy the Regulus. The nuclear sub USS *Hallibut* could carry 5 of the missiles.

Fleet surface ships and aircraft carriers also carried the Regulus. When launched from an aircraft carrier, the missile could be controlled by a carrier-based aircraft.

The SSM-N-9 was the second generation missile with a range of 1,200 miles. It was capable of Mach-2 flight. It was superseded by the Polaris missile. After their retirement, they were used as target drones.

The Soviet equivalent of the *Regulus* was the P-5 *Pyatyorka*. After 1960, the Navy's shifted from cruise missiles to ballistic missiles, with vastly increased range. Today, subs can launch armed drones for shore bombardment missions.

Navigation systems

For the ballistic missiles to be effective, they have to reach their target. In the ground-based systems discussed before,for the Atlas and Titan, the missiles are launched from a surveyed location to a desired target. The missile only burns its engine for a couple of minutes. After that, it is on a ballistic trajectory, and can't be steered (without a lot more technology). Actually, the newer missiles with multiple payloads can launch each payload to a different target. But, let's say it is the 1960's. How does the missile know where it is? GPS! Oh, wait, that wasn't operational until 1995. There's a couple of bad options. LORAN was developed

during World War-II to assist ships' and planes' navigation. It had an accuracy of tens of miles. Sure, that's close enough for nuclear weapons, but a better system was needed. Loran use has now been discontinued. So the Navy, not having a satellite navigation system, invented one. It was called *Transit*, and today, GPS is the latest update.

The Transit work was done by DARPA, and the Applied Physics Laboratory of the Johns Hopkins University, starting in 1958. The first successful launch to polar orbit was in 1960, and its was operational by 1964. The Soviets deployed a sat-nav system as well. Five satellites are needed for reasonable use around the globe. Spares are kept in orbit as well. There were 38 satellites in the Transit system.

In submarine missile guidance, the boat's navigation system provides the missile with the launch point. The target's coordinates are known. The Ships Inertial Navigation System, SINS, has been updated to use GPS as well. The Trident I & 2 supplemented their guidance by stellar reference.

The boats

This section discusses the evolution of U. S. Navy subs, the *Polaris*, the *Poseidon*, and the *Ohio*-class. The first ballistic missile sub was done by the Soviets in 1955. They equipped one of their existing diesel subs with a single ballistic missile tube in the sail. Then they launched the first ballistic missile from a sub in 1955. They put two missiles on five additional subs, and they entered service by 1957. These were followed by 23 purpose-built missile subs, with 3 launch tubes each. The missiles could not be launched from underwater.

In 1959, the first nuclear-power missile sub was the USS *George Washington, with* 16 Polaris missiles. The ship was the previous USS *Scorpion,* cut in half, and with a 130 foot long missile compartment added. By 1967, the United States had 41 subs with ballistic missiles.

U. S. subs have two crews, one operating the sub and the other on dry land. They are referred to as the Blue crew and the Gold crew. With 2 crews, the boats can be continuously deployed. They can also be re-provisioned at sea.

Polaris

The Polaris missile (UGN-27) was a two-stage solid-fuel nuclear-armed submarine-launched ballistic missile (SLBM) built during the Cold War by Lockheed Corporation of California for the United States Navy. It included Inertial guidance and Thrust vectoring for steering.

Size was an issue. A guidance computer small enough to fit through a submarine hatch was developed by 1958, by TRW, the AN/UYK-1. It was used to interpret the Transit navigation satellite data and send guidance information to the Polaris, which had its own guidance computer made with ultra miniaturized electronics, very advanced for its time. There wasn't much room in a Polaris sub for the 16 missiles. The details of these computers are still classified. The Ship's Inertial Navigation System (SINS) was developed earlier to provide a continuous dead reckoning update of the submarine's position between position fixes via other methods, such as LORAN. This was important in the first few years of Polaris, because the Transit satellite system was not operational until 1964.

There were a total of 42 Polaris missile boats from 1957 through 1963, but all were retired. The next 31 boats were designed for Polaris, but mounted Poseidons. Their last patrol was in 1994.

The missile is launched from its tube by high pressure steam. The engine ignites when it is about 30 feet away from the sub. The first model of the Polaris had a range of one thousand nautical miles, improved to 2,500 nm by the A-3 version, which also carried multiple warheads.

By 1965, microchips similar to the ones Texas Instruments made for the Minuteman II were being purchased by the Navy for the Polaris. The Minuteman guidance systems each required 2000 of these, so the Polaris guidance system probably used a similar number. To keep the price under control, the design was standardized and shared with Westinghouse Electric Company and RCA.

The support facilities for test launches are at Cape Canaveral, in Florida.

The Polaris missile was influenced by the design of the Army's Jupiter ICBM. Polaris was developed by Lockheed specifically for submarine use. The guidance system was designed by MIT's Draper Lab, and implemented by GE and Hughes. Lessons-learned from the Minuteman Project were applied. It had thrust vector control. There were three models of the Polaris missile.

The missile was popped out of its tube while the sub remained submerged. The engine was ignited when the missile was some feet into the air. The first underwater launch was accomplished in July of 1960, from the USS *George Washington*. By 1978, there were 41 boats carrying 16 missiles each.

The missile was 28.5 feet long, 4.5 feet in diameter, and weighed in at 28,800 pounds. It could carry its single warhead to 1,000 nautical miles. The second version was 2 1/2 feet longer, but still fit in the same tube. The third version, the A-3, had a range of 1,500 miles, and carried three warheads.

The first Polaris sub, USS *George Washington*, SSDN 598, launched a Polaris off the coast of Cape Canaveral in July 1960. Three hours later, it launched a second. It went 1,200 miles downrange. The Polaris A1 was retired October of 1965. Five subs had carried 16 each of them. The missile was retired in October of 1965. The Polaris A2 had a first launch, from a submerged sub, in 1961, from the *Ethan Allen*, SSBN-608. It was retired in 1974. The *Ethan Allen* class subs followed the *George Washington* Class.

They were purpose-built as missile carriers. They had the number of torpedo tubes reduced to four. By the mid 1970's they carried the A3 variant of the Polaris.

The Polaris A3 was first launched from the submerged *Andrew Jackson*, SSBN 619, in 1963. It was declared operational in September of 1964. It had a 2,500 nautical mile range. It served until 1979, and a total of 10 boats carried it.

The *George Washington* was built at the Electric Boat Division of General Dynamics in Groton, CT in 1958. The hull was originally going to be an attack sub, named *Scorpion*. Re purposed, she had a 130 foot section inserted for the missiles. She served in the Atlantic, later going to the Pacific. In April of 1981, while running at periscope depth in the East China Sea, she was hit amidships by a Japanese cargo ship, unaware of their presence. She surfaced, to look for the ship, but there was a heavy fog. She put into port for repairs to her sail. The Cargo vessel sank with the loss of two crewmen. In her career spanning 25 years, she conducted fifty-five patrols. Her missiles were unloaded to comply with the SALT treaty, and she continued to serve as an attack sub, out of Pearl Harbor. She went back to New London in 1983, where she was decommissioned. She proceeded to Puget Sound, for recycling.

The British Royal Navy *Resolution* class subs also carried Polaris. The US supplied the missile sans warhead. This program involved 4 Polaris-class, and 4 Trident class.

Five older vessels were not carried over to the Poseidon fleet. These subs were re-purposed as attack vessels, with no ballistic missiles, to comply with the SALT II treaty.

Poseidon

Polaris was replaced by Poseidon in 1972, which could launch multiple warheads. It was a two-stage vehicle, 2 feet longer than Polaris A3. The tubes were long enough to hold them, though. It also had a somewhat larger diameter.

The *Poseidon* missile (UGM-73A) was the follow-on to the

Polaris. It was a solid fuel unit, with two stages. It had a greater range than the *Polaris*, 2500 NM, but at the same time, fit in the same Polaris launch tubes. It was capable of carrying multiple warheads. It used thrust vectoring for control, and had an internal guidance system. It was operational by March 1971. It used the Honeywell HDC-701 flight computer from the Minuteman. It eventually was deployed on 31 boats.

First launch submerged was in August of 1970, from the *James Madison***,** SSBN 627. The missile achieved a 2,500 mile range, and could carry fourteen independent warheads. First test launch was in 1968 from a surface ship. In all, 31 *Lafayette*-class subs carried Poseidon missiles. By 1992, the missiles were removed from service.

The *Poseidon* missile was built by Lockheed Corporation. It weighed more than 64,000 pounds, and was 34 feet long, 74 inches wide. The last Poseidon missile was off-loaded in 1992, replaced by Trident.

Ohio-class and Trident

The *Ohio-class* was the third generation of submarine to carry ballistic missiles. These are the current generation in use at this writing. There are 18 missile boats, and 4 cruise missile carriers. These boats are big, displacing some 18,750 tons of water. They are built at General Dynamics Boat. They have nuclear propulsion. They were built over a span of ten years, starting in 1981. It is expected that they will be in service until 2029. Studies are ongoing for their replacement.

The SSGN-726 *Ohio* was the first sub of this class, so supplied the class name. She carry's 24 Trident-II guided missiles. These have a 12,000 nautical mile range. It is a three stage vehicle, 34 feet long, and weighs in at 73,000 pounds. First launch was from Cape Canaveral in 1977. The first sub launch was from the USS *Francis Scott Key* in October of 1979. *Ohio* had the first female sub officer on it's Gold Crew.

There are 12 Ohio-class subs, 8 holding Trident missiles. Four of the boats carry cruise missiles only. This is in alignment with an International Agreement on the maximum numbers of warheads. The cruise missile boats are *Ohio, Michigan, Florida, and Georgia.*

They are 560 feet long with a beam of 42 feet. They weigh some 16,764 metric tons. According to the open literature, they can travel at 12 knots on the surface, 20 knots submerged. They can operate fro 60 days submerged, when the food supplies need to be refurbished. Their maximum test depth is 800 feet. They carry a crew of 15 officers, and 140 enlisted men. They also carry four 21 inch torpedo tubes in the bow. The boats converted to cruise missile carriers have 22 tubes, for Tomahawk missiles.

The Trident I C4 has a range of 4,000 NM, and has multiple war heads (MIRV) that can be individually targeted. It is a three stage vehicle. It could in theory be back-fitted to older Poseidon subs, but this is prohibited by treaty. The missile was first pad-launched in January of 1977.

The Trident-II D5 was larger, and took advantage of the entire launch tube volume. It was deployed in 1990.

The missile payload weighs 6,170 pounds, and the missile is 83 inches in diameter. It uses six onboard computers. The Ohio class subs can use GPS for position data.

Tenders

Subs have dedicated tenders for resupply and support at sea. The Navy's two tenders are the USS *Emory S. Land* (AS-39) and USS *Frank Cable* (AS-40). These are deployed in the Atlantic and the Pacific. The tenders resemble the infrastructure of a small town, having, in addition to food and supplies, spare parts, work shops, medical services, and most importantly, the mail.

The *Emory* displaces 14,000 tons light, and 23,000 tons full

loaded. She is 650 feet long. With a beam of 85 feet. She uses a steam turbine to drive her propellers. She can achieve 18 knots, and she is armed.

Other countries

The United States is not the only country with ballistic missile submarines. The United Kingdom, France, Soviet Union, China, and India have these as well. Except for India, all of the countries are permanent members of the United Nations Security Council. These countries were Allies in World War-II.

India is developing a class of nuclear ballistic missile submarines under the class name of *Arihant*, *Slayer of Enemy's* in Sanskrit. The first vessel, of the same name as the class, was commissioned in 2016. The vessel has four launch tubes, and can carry twelve single-warhead missiles.

China has a People's Liberation Army Navy Submarine Force. Construction on the first boat has not yet begun.

The Russian *Typhoon* class sub were the largest subs ever built. *Typhoon* is the NATO designation; the Russian name translates to *Shark*. They displace 48,000 tons, submerged. Further construction was halted in 2012 due to cost. The last *Typhoon* has reached end of service. The sub could stay submerged for up to 120 days. It included 6 torpedo tubes and 20 ballistic missiles with MIRV warheads. They can travel at 28 knots. Six boats were built. Previous classes of subs from the Soviet era included the Delta-II and Delta-IV (NATO designation). The new class is the *Borei*.

The North Koreans have missile submarines. In May of 2015, they launched a ballistic missile from one. There has subsequently been five more shots. Supposedly, the country is building five more boats. They are of the *Sinpo* class, with the KN-11 missile. Details are sketchy.

This is a little bit off topic, but is interesting along the lines of other Navy systems discussed. In World War-2, the Imperial Japanese Navy had a special submarine, the I-400. It carried

aircraft, to any location in the world. A fleet of 18 was envisioned, but only three were completed. A requirement was to be able to reach the United States Coast, un-refueled.

On the top of the craft, amidships, was a waterproof hanger, more than 100 feet long, and 10 feet in diameter. The sub also maintained torpedo tubes, and anti-aircraft guns.

There were three Aichi M6a Seiran float planes, that could be launched and retrieved. These could be equipped with an 1,800 pound bomb, and deliver it to a target more than 600 miles away. The wings were folded and rotated to fit in the hanger. A crew of four could launch the aircraft in 30 minutes. The planes were sent on their way with a 85 foot compressed air catapult. The procedure was similar to launch and recovery of reconnaissance aircraft by Japanese cruisers.

One proposed mission was a strike against the Panama canal. If even one set of locks were damaged, the logistics of moving war material would get vastly more difficult for the U. S. The Miraflores locks on the Pacific side were the primary target.

The Japanese went so far as to construct a full scale wooden model of the Gatun gates. At this point, fifteen Allied Aircraft carriers were assembled to make massive raids against the Japanese mainline. These became the new target. It was to be a Kamikaze mission. In direct violation of the rules of war, the planes were painted with American insignia. The pilots themselves considered this dishonorable.

The attack was thwarted when the submarine was damaged by an American aircraft, and then surrendered to an American destroyer.

Another scheme involved using the sub's plane to drop biological weapons near San Diego. The Japanese surrender after the second nuclear weapon was used prevented this attack, and prevented a massive death toll in Southern California.

The Americans seized, examined, and then sank the Japanese submarines off Hawaii, to prevent the Russians from examining them.

Historical tidbit

In the U.S. Civil War, the Confederacy had at least multiple submarines, only one of which, the *CSS Hunley*, saw action. It sank a Union warship, the USS *Housatonic*, but its crew tragically died as well.

The *Hunley* was 40 feet long, and built in 1863 in Mobile, Alabama. The inventor, Horace Hunley lost his life on one of the test-runs. The South had three private submarine projects, bankrolled by Horace Lawson Hunley, James McClintock, and Baxter Watson. The Pioneer, also by Hunley, was abandoned and scuttled as Union troops approached New Orleans. It was scuttled in a canal, but later raised by Union troops.

The South had at least three private submarine projects, bankrolled by Horace Lawson Hunley, James McClintock, and Baxter Watson. The Confederacy had offered a $100,000 prize to anyone would destroyed an Ironclad, and $50,000 for every Monitor sunk.

William Cheeney developed a submarine before the *Hunley*, name unknown. It was the first to conduct a combat mission in the summer of 1861. This was noticed by a Union spy, a Mrs. Baker, who reported to Union Spy Chief Pinkerton. She also reported a second boat in work at Tredegar. This news drove the development of anti-submarine nets for the Navy. Those worked, as evidenced by the thwarted attack on the USS *Minnesota* in October of 1862.

The North had the submarine USS *Intelligent Whale*. She never saw action, and currently resides at the National Guard Militia Museum of New Jersey in Sea Girt. She was completed by 1866 by the newly formed American Submarine Company. The ship failed her acceptance trials in 1872, and was rejected.

Both the USS *Alligator* and the CSS *Pioneer-II* were lost at sea, sunk in a gale, location unknown.

The *Pioneer-II* is thought to lie in Mobile Bay. It was a 5-man sub, launched in January 1863.

The *USS Alligator* was being built in 1861, the Navy's first submarine. It was built in Philadelphia. It was preceded in the Revolutionary War by Bushnell's *Turtle,* which was not successful. The *Alligator* was the design of a French Engineer, Brutus Villeroi. He served as a supervisor of construction during the early phased. It was built by the firm of Neafie & Levy, a Philadelphia shipbuilding firm. The ship was 30 feet long, and about 6 feet in diameter. It was divided into watertight compartments internally. It carried a crew of 18. It was originally built with 16 hand-powered paddles, but was later retrofitted at the Washington Navy Yard with a hand cranked propeller. It had two floats to supply breathing air to the crew, operated by pumps, and it had an air purifying apparatus. There was an airlock, so crew could leave and return to the ship while it was submerged. This would allow the attachment of an electrically operated mine to enemy vessels. It was supposed to be completed in 40 days, an ambitious schedule, but took 180. It was launched in May of 1862. She went to the Navy Yard to be fitted out, and was commissioned into the service.

In dive tests in the Potomac, she almost sank. It was found that a crew of 18 could not maintain headway, let alone progress against the tidal current, near the Navy Yard. She was later fitted with a propeller and hand cranks. Her primary mission of destroying the *Virginia-II* was seen as non-feasible

41 for Freedom

The title refers to the 41 nuclear powered ballistic missile submarines of the Navy Fleet Ballistic Missile Program. These were subs of the *George Washington, Ethan Allen, Lafayette, James Madison, and Benjamin Franklin* Classes. These were superseded by the Ohio class subs. The last boat of the 41, USS *Kamehameha,* was decommissioned in 2002 at age 37.

Subs in classes

This section shows the various submarines in their classes, in the

order built.

Ohio Class – Trident missiles

- Ohio - SSGN
- Michigan - SSGN
- Florida - SSGN
- Georgia- SSGN
- Florida - SSGN
- Georgia – SSGN
- Henry M. Jackson - SSBN
- Alabama - SSBN
- Alaska - SSBN
- Nevada - SSBN
- Tennessee - SSBN
- Pennsylvania – SSBN
- West Virginia – SSBN
- Kentucky - SSBN
- Maryland - SSBN
- Nebraska - SSBN
- Rhode Island - SSBN
- Maine - SSBN
- Wyoming - SSBN
- Louisiana - SSBN

Lafayette Class – Polaris or Poseidon

- Lafayette
- Alexander Hamilton
- Andrew Jackson
- John Adams
- James Monroe
- Nathan Hale
- Woodrow Wilson
- Henry Clay
- Daniel Webster

Ethan Allen Class – Polaris Missiles

- Ethan Allen
- Sam Houston
- Thomas A. Edison
- John Marshall
- Thomas Jefferson

Ohio class – Poseidon missiles

- Ohio
- Michigan
- Florida
- Georgia
- Henry M. Jackson
- Alabama

- Alaska
- Nevada
- Tennessee
- Pennsylvania
- West Virginia
- Kentucky

James Madison Class – Trident missiles

- James Madison
- Tecumseh
- Daniel Boone
- John C. Calhoun
- Ulysses S. Grant
- Von Stuben
- Casimir Pulaski
- Stonewall Jackson
- Sam Rayburn
- Nathaniel Greene.

Compare & Contrast

Polaris	A1	A2	A3	
Length	28	31	32	feet
Diameter	54	54	54`	inches
Weight	28,000	32,500	35,700	pounds
Stages	2	2	2	
Guidance	inertial	inertial	inertial	
Range	1,200	1,500	2,500	nautical miles

	Poseidon	Triton-1	Triton-2	
Length	34	34	44	feet
Diameter	74	74	83	inches
Weight	64,000	73,000	130,000	pounds
Stages	2	3	3	
Guidance	inertial	- inertial-stellar-		
Range	2,500	4,600	4,600	nautical miles

Afterword

Ballistic missile armed subs are an expensive, necessary evil, because nations can't play nice. Submarines, particularly the nuclear power variety can roam the Oceans undetected. They have the ability to launch nuclear tipped missiles from any point, to designated targets. Under the concept of “mutually assured destruction” (MAD), subs provide a balance of power. One of the most technologically advanced systems on the planet, subs are their own ecosystem.

Glossary of Terms

AFB – Air Force Base.
ABM - anti-ballistic missile.
Atlas – ground based ballistic missile and launch vehicle.
AN/UYK-1, computer small enough to fit through a submarine hatch; used for missile guidance.
APL – Johns Hopkins University, Applied Physics Lab.
Boomers – slang for ballistic missile submarine.
CNO – Chief of Naval Operations.
Cpu – computer's central processing
CSS – consolidated support ship
DARPA – Defense Advanced Research Projects Agency.
Dorsal – top side.
Fairwater – see sail.
FBM – fleet ballistic missile, aka, Boomer.
GDEB – General Dynamics Electric Boat, Groton, CT.
GEMS – Generalized Energy Management Steering.
GPS – Global Positioning System, satellite-based.
ICBM – intercontinental ballistic missile.
INS – Inertial Navigation System
JATO - "Jet" assisted take-off, using a solid rocket motor.
Jetevator – steering control for a rocket nozzle. Ball and Socket arrangement.
Khz – kilo hertz.
Kva – unit of power, kilo volts-amps.
LORAN – radio based navigation system; circa World War-2.
Mad – mutually assured destruction.
Metric ton – 1,000 kg, 2204 pounds.
MIRV – multiply independently targeted reentry vehicle – missile with multiple warheads.
NATDAN – North American Transistorized Digital Analyzer.
NATO – North Atlantic Treaty Organization.
NavSat – navigation satellite.
NGA-I – (U.S.) National Geospatial-Intelligence Agency.
Nm – nautical mile.

NNSS - Navy Navigation Satellite System (Transit).
OBC – onboard computer.
OTSU – Operational test support unit.
Periscope depth – approximately 50 feet.
PERT - Program Evaluation and Review Technique.
Polaris - submarine launched ballistic missile.
Poseidon - submarine launched ballistic missile.
Regulus – SSM-N-8A, 2nd generation cruise missile
Sail – on a submarine, the tower that extends from the top of the hull.
SALT – strategic arms limitation talks. SALT-1 (1972) allowed each country 656 missile tubes.
SecNav – Secretary of the Navy.
SINS - Ships Inertial Navigation System
SLBM – submarine launched ballistic missile.
SLCM – cruise missile on a submarine.
SNLE - sous-marin nucléaire lanceur d'engins.
SS – Ship, submersible.
SSB - submersible ship ballistic (missile).
SSBN – submersible ship ballistic (missile), nuclear.
SSG – cruise missile submarine.
SSGN - cruise missile submarine, nuclear.
STARS, Strategic Targeting System,
SUBRON – submarine squadron.
Titan – ground based ballistic missile and launch vehicle.
Transit – first operational navigation satellite system.
Trident – submarine launched ballistic missile.
U-boat – (German) unterseeboat.
UGM – U. S. military designation for a underwater launched attack missile.
V-1 – German World War-II first generation cruise missile.
V-2 – German World War-II ballistic missile.
WSEG – Weapons System Evaluation Group.
VLS – (submarine) vertical launch system.
XNG – (USAF) auto-navigator.

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Where to see

This is not an all-inclusive list.

Cruise missile *Regulus* - can be seen ready for simulated launch on board USS *Growler* at the Intrepid Sea-Air-Space Museum in New York City, and Point Mugu Missile Park, Naval Air Station Point Mugu, California. There is also one at the Smithsonian Steven F. Udvar-Hazy Center in Chantilly, VA.

Ballistic Missile *Polaris* – Air Force Space & Missile Museum, Cape Canaveral, Florida; Imperial War Museum, London.

Ballistic Missile *Trident* – Smithsonian Steven F. Udvar-Hazy Center in Chantilly, VA. (near Dulles Airport).

Ballistic Missile *Poseidon* - Smithsonian Steven F. Udvar-Hazy Center in Chantilly, VA. (near Dulles Airport).

Cruise missile *Loon* - Smithsonian Steven F. Udvar-Hazy Center in Chantilly, VA. (near Dulles Airport).

Seiran submarine-launched aircraft- Smithsonian Steven F. Udvar-Hazy Center in Chantilly, VA. (near Dulles Airport).

The *CSS Hunley* was located in 1995, and recovered in 2000. It is in the Warren Lasch Conservation Center museum in North Charleston, South Carolina.

The sail from the *George Washington*, the first Polaris sub, is at the Submarine Force Library and Museum at Groton, Connecticut.

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